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PHILOSOPHICAL TRANSACTIONS.

Januar. 29. 1676.

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New Experiments made and communicated by the Honourable Robert Boyle Esquire, about the Superficial Figures of Fluids, especially of Liquors contiguous to other Liquors.

S I R;

IN compliance with your Curiosity, I herewith send you my rude Notes about the Superficial Figures of contiguous Liquors, which, belonging to a Paper (concerning the *Pores* and *Figures of Bodies*,) whereof they made the last part, and being themselves very indigested; I should by no means venture to expose them even to a less Critical eye than yours, if I did not hope, that, though a more discerning Reader will sooner discover their Imperfections, yet he may be more inclin'd than an ordinary one would be to think them not useles Trifles; since, if these Trials and Hints, as mean as they are, be prosecuted by Naturalists that have Mathematical Heads, per-

haps they may conduce more to the *Physical Theory* of the Grand *System of the World*, than at first one would suspect. And that I may leave you and your Ingenious Friends the greater opportunity and freedom to exercise their Sagacity on these *Phænomena*, I have purposely forbore to engage in Speculative Discourses upon them, contenting my self to have faithfully recited Matter of fact, and thereby to have sprung game for those that have more leisure and hability to flie at it.

—What has been said about the *Pores of Liquors*, may be somewhat illustrated or confirm'd, if I subjoyn to it some of the Trials I have made about the *Surfaces of Fluids contiguous to other Fluids*. For this being, for ought I know, a neglected Subject, and the little that has been taken notice of about it, consisting of a few slight and casual Observations, that seem to have been rather presented to us, not to say obtruded upon us, than designedly made by us; I many years ago thought, it might be worth while to spend some hours upon Experiments of this sort: Which I was especially induc'd to do, because I think, one may probably enough suppose, that in the Tract of the Universe that is yet known to us, there is not the hundredth, perhaps not the thousandth, part, that is form'd into *Solid Bodies*, such as the Earth, the Moon, and the other Planets; and consequently all the rest is made up of Celestial Fluids and the Atmospheres of Solid Globes, which, for ought we know, though not manifestly differing in transparency, may be determinated by distinct Surfaces. So that, to observe and consider the effects of the congruity and incongruity, that Liquors, or such fluid Bodies, as directly or otherwise fall under sensible Observation, have, when they are contiguous to one another, or to the surfaces of Solid Bodies, may not only improve what is yet known about the Ascention of Liquors in small Pipes, but may perchance serve to illustrate the formation of those great Masses of Matter, of which the Divine Architect has fram'd the Mundane Globes, and some other considerable parts of the Universe, especially if we admit the *Cartesian Hypothesis*, *That the Sun, and all the Fixt Stars are Fluid Bodies*.

The Cause, why Water in narrow Pipes ascends above the level of the surrounding water, having been already enquired into by some Ingenious men, and particularly by Mr. *Hooke*, I shall

shall not now discourse of that Subject, nor so much as mention what I have tried about it ; but shall rather take notice, that, because I suspected, that the Concave Figure, which may be observed in the surface of Water included in slender pipes, may, at least in great part, depend upon its relation to the Contiguous fluid, which, in ordinary cases, is the *Air* ;

I thought fit to try whether this Concave Figure Exp. I. would not be altered by substituting another Liquor in the room of the Air : And accordingly having procured a strongly *Alcalizat Menstruum* (I used that made of fixt Niter, dissolved by the moisture of a Celiac) into a pipe of glass, seal'd at one end, and not full a quarter of an Inch in bore ; that the Cavity, which in a greater breadth would seem less deep, might be the more conspicuous : We gently poured on it some highly dephlegm'd *Spirit of Wine*, which we knew would not mix with it, but swim above it, and presently, as we had guess'd, we found the Figure of the surface of the lower Liquor changed, and the cavity quite destroyed ; the surface that seem'd, as it were, common to the two contiguous Liquors, appearing flat or horizontal. And such a level Superficies we had, by putting those two Liquors together in a much wider Glass.

We found also, that by employing *Oyl of Turpentine* Exp. II. instead of Spirit of Wine, the Liquor did almost totally lose its Cavity.

But if, instead of deliquated Tartar, we put com- Exp. III. mon water into the Pipe, we found this Liquor to retain its Concave Surface, though we put to it some Oyl of Turpentine and left it to rest upon the water a good while.

In regard that, when Oil and Water are put together, the Oil that has been employed to produce the *Phænomena*, wont to be afforded by their Contact, has usually been *common Oil*, as that of Olives, which is lighter than water ; I thought it expedient to try what Figures would be afforded by the Surface of water and also by that of Air, when those Fluids should become contiguous to an Oil, heavier than water : of which sort Chymistry had afforded me more than one or two besides the Essential oils of Cloves and Cinnamon : Having therefore provided some pure oil of the Exp. IV. *Gum of Guajacum*, and poured a little of it into a

flender pipe, we found the upper *superficies* of it to be concave; almost, if not altogether, like that which water would have had in the same pipe. But when I put a little Water upon this Oil, it presently changed the figure of its surface, which became visibly, though not very much, protuberant or Convex.

And in regard this Oil, though heavier than Water, is not so heavy as deliquated salt of *Tartar*, I thought fit
 Exp. V. to try, whether the *Phænomenon* would not be differing upon the Contact of these two liquors; and accordingly having put some Oil of *Tartar* into the slender pipe, and put some drops of the Oil of *Guajacum* to it, we found, that this liquor did not manifestly alter the Concave figure of the surface of the liquor *Alcali*, as the Oil of *Turpentine* had done: And having, for Curiosity sake, warily poured a little Water upon the Oil of *Guajacum*, I found, as I had reason to suspect, that the upper *superficies* of it changed presently from a Concave Figure to a Convex, so that this Oil in the midst of the other two liquors appear'd like a little red Cylinder, which, instead of having Circular *bases*, was protuberant at both ends, but more at that which touched the Oil of *Tartar*.

To vary a little the Experiment, I put some *Essential Oil* (as Chymists call it) of *Cloves* into a new slender
 Exp. VI. pipe, and having observed it to be somewhat Concave at the top where it was contiguous to the Air, we caused a little Common water (perhaps a quarter of a spoonful or less) to be put to it, and found, as we expected, the surface of this Oil also to become tumid. And in regard this Liquor as well as the forementioned Oil of *Guajacum*, though it were so heavy as to sink in water, would not do so in deliquated Salt of *Tartar*, we did, into another slender pipe, put first some of this last nam'd liquor, then some of the Aromatic Oil, and lastly a little Common water; by which means we found, that the little Cylinder of Oil did, like that of the Oil of *Guajacum*, appear convex at both ends; but was unlike it in one Circumstance, that the Oil of *Cloves* appear'd more convex at the upper end where 'twas contiguous to the water, than at the lower, that lean'd upon the surface of the Oil of *Tartar*.

Having

Having made these Trials, to alter, by another contiguous fluid than the Air, the Concave *superficies* of Water and some Aqueous liquors, I proceeded to try, whether a change would not likewise be made on the convex figure of the surface of *Quicksilver* included in the like slender Glasses; and accordingly, having taken one that was much longer, but of the like bore with the former (for to make the Trials more uniform, I had caused a long Pipe to be by the flame of a Lamp unequally divided into several short ones) we put into it a small quantity of *Quicksilver*, and having taken notice how the upper *superficies* swelled in the middle above the level of the parts where it touched the Glass, we poured some Water upon it, and found a manifest and considerable depression of the Surface, though the protuberance were not quite suppressed.

This *Phænomenon* having been for greater security several times repeated, I thought fit to try, what variation would be made, by the greater or lesser height of the water incumbent on the *Mercury*. And sometimes it seem'd, that, when the aqueous Cylinder was much longer, the depression of the *Mercurial* surface was somewhat greater. But this did not so constantly happen: But we often observ'd, that, though a very little Water sufficed by its contact to make, in the judgment of the eye, a manifest abatement of the Protuberance of the *Quicksilver*, yet it had not the same effect on that ponderous Fluid, that it had, when, being increased almost as high as the length of the Pipe would permit, a greater weight of it was incumbent on the *Mercury*. For then I manifestly perceived and shew'd to others, that the surface of the *Quicksilver* being depress'd almost to a Level in those parts of it that were near the inside of the Glass, there was about the middle of the surface an elevation of *Mercurial* water, that appear'd to be, rather more than a half Globe, and was to the height of its full *Semidiameter*, rais'd above the rest of the *Mercurial* surface, and in that state it continued as long as I thought fit to let it do so. And lest this Tryal should impose upon me, I caused it to be more than once repeated; and, the better to confirm it, I afterwards caused the incumbent Water to be little by little suckt up, and found, as I expected, that when the Incumbent water began to be

too much shorten'd, the little Teat or Segment of sphere, lately mention'd, began to be somewhat flatten'd, and subsided more and more as the Water was further taken off.

Because the common *Atmospherical* Air we breath is a Fluid body abounding with grosser particles, and is by
Exp IX. divers Philosophers probably supposed to be much more dense and heavy than the *Æthereal* substance, that makes the other part of the Atmosphere; I thought fit to try for their sakes, whether or no the *superficial* Figure of Liquors would be alter'd by having the contiguous Air withdrawn from about them, and so being left to be touch'd by the purer *Æther* without it; and accordingly having conveyed into one of our *Pneumatical Receivers* a couple of such Slender pipes as have been already described, one of them furnish'd with Common water, and the other with Quicksilver, we caus'd the Common air to be diligently pump'd out, without observing any sensible change in the Concave Figure of the water: but as for the Quicksilver, I knew not what to conclude about it. For having repeated the Trial twice or thrice, the *Mercury* sometimes seem'd manifestly to swell to be more protuberant upon the Exhaustion of the Receiver, than when it was put in, especially when its Figure was attentively view'd, and the External air, that was pump't out but slowly, was suffer'd to reenter with all convenient celerity. But that which yet kept me doubtful was, that I observed, that upon the diligent withdrawing of the Airs pressure on the Quicksilver, there disclos'd themselves in it some little bubbles, which I fear'd we had not been able to free it altogether from, and which might be suspected to have some interest in the *Phænomenon*; which though it was at that time hinder'd by some occasions from prosecuting further, yet I think it may be well worth the while, because, if any sensible change do certainly appear to be made in the Superficial figure of the *Mercury*, it may teach us somewhat relating to the Constitution of the *Æther*, which seems to make up far the greater part of the Universe known to us: And I should not in that case think it impossible, that by exposing many and differing Liquors to its Contact *in vacuo Boyleano* (as 'tis call'd) some discovery may be made of differing Substances, whereof one may suspect the *Æther* it self not to be uncapable. But to leave suspicions that probably

bably will be thought Chimerical, I shall only add, which I forgot before, that we conveyed into our *Receiver* a clear Chymical Oil that was heavier than Water, and, whilst 'twas contiguous to it, had not a Concave but a Convex surface, and having placed the Pipe furnish'd with both Liquors in the *Pneumatical Receiver*, we pump't out the Air without finding that the Oil sensibly altered its Protuberant Surface, as neither did the Water lose the Concave figure of its upper surface.

When Clouds are condens'd into Rain, and lower aggregates of vapors into Dew, 'tis suppos'd to be obvious, that the drops of those Meteors do, in their passage through the Air, (which to them is a heterogenous Fluid) acquire a round figure; and when we shake Oil into Water, the portions of the former fluid, during the little time they remain distinct (for they quickly reunite into masses) are found to be globular. But these *Phænomena* are too few and too transient to afford any considerable Observation of the Figures of Fluid bodies, especially if they be quiescent, and every way encompass'd by other Fluids. Wherefore I thought fit to try what I could do with Chymical Liquors unapt for mingling, to produce *Phænomena* that may last long enough to allow Us to observe them attentively, and in some cases to vary them.

For this purpose, I first took sixt *Aiter*, (or, which is analogous to it, Salt of *Tartar*) resolv'd *per De-* Exp. X.
liquium into a transparent Liquor, and having fill'd a clear Vial half full with this, I poured on it a convenient quantity of Vinous spirit exactly rectified, that there might be no Phlegm to occasion an union between the two Liquors, which ought, as ours did, to retain distinct *surfaces*, and speedily regain them though the Glass were well shaken. Then having found by a Trial formerly mention'd, that common Oil of *Turpentine*, if employed in a competent quantity, will not totally (and much less will readily) dissolve in Spirit of Wine, and also having observ'd (what may seem somewhat strange) that if this Spirit of Wine be exquisitely dephlegm'd, the Oil, though a Chymical one, will not swim on it, but sink in it; I warily let fall some drops of the Oil into the Spirit,
and

and had the pleasure to see, as I expected, that they fell towards the bottom of the Glass till their descent was stoppt by the horizontal (for it was not concave) surface of the *Alcalizat* liquor of fixt *Alter*. And because my design was chiefly to observe the superficial Figure of a Fluid encompassed by other Fluids without touching any solid body, I shall here take notice of the chief *Phænomena* that were produc'd of that kind, without staying to enquire into the *Causes* or the *Consequences* of them.

1. If the Oily drops were but small, they seem'd to the Eye exactly enough spherical. For the Oil differing but very little in specific Gravity from the Spirit of Wine, the drops did but just touch the surface of the subjacent *Alkali*; and the same drops being but small, their own weight was not great enough visibly to depress them, and hinder that roundness which the pressure of the Ambient Spirit, or their own Viscosity endeavour'd to give them.

2. If an Aggregate of drops were considerably bigger than those newly mention'd, as if it had about a third part of an Inch in Diameter, it would then manifestly lean upon the *Alcalizat* liquor as upon a floor, and appear *somewhat* elliptical, (for some little part of the bottom was a Plain;) the weight of the upper parts depressing the drops, and making the horizontal Diameter somewhat longer than the transverse.

3. If a yet greater portion of Oil were let fall upon the heavy Liquor, it would for a pretty while appear in the form of a somewhat imperfect Hemisphere, or some other large section of a Sphere, the lower part being cut off; (as if a Globe were divided by a Plain) by the horizontal surface of the deliquated Salt.

4. But if the quantity of Oil were not too great, 'twas pretty to observe, that, though at first putting in, it did perhaps spread it self over the subjacent Liquor, and lie as 'twere flat upon it; yet by little and little, (for 'twas but slowly)

slowly) it would by the action of the Ambient, concurring with its own tenacity, be crowded together into a Figure of a lesser surface, and consequently less hindering the motions of the Vinous liquor. For by the action of this Spirit, the Oil would by degrees be raised above the surface of the fluid *Niter*, and be reduc'd to the Figure, either of half a Globe, or of a greater segment of a Globe, or even of an imperfect *Ellipsis*, according as the bulk or weight of the Oil made it more or less apt to resist the action of the Ambient spirit, to whose effect, as I lately intimated, the natural viscosity of the Oil might (more or less) cooperate, as also might the weight of the *Spirit of Wine*, which in great part disabled the endeavour of the Oils gravity to make its Figure less convex.

5. Though these Globuls or portions of Oil, did oftentimes readily mingle, when they touched one another, yet divers times also we observed, that having warily approached them, we were able (as if some odd subtle matter, that the Eye could not discern, interposed, to keep them unconfounded;) to make them touch without mingling: Insomuch, that we have with pleasure made them so far bear against one anothers *surfaces*, as manifestly to press them inwards, though being parted they would presently resume their former Figure: Which circumstance suggested to me Suspicions, that I cannot now stay to name. But in case any of these Oily portions came by a more pressing contact to be united, they would then alter the Figures they had whilst separate, and take another, suitable to the bulk of the Aggregate.

6. When a large portion of Oil rested upon the Saline liquors, if then the Ambient spirit were moderately and warily agitated, 'twas not unpleasant to observe the various Figurations, which the convex and protuberant part of the mutilated Globe would be put into by these shakes, without any visible solution of continuity, or considerable motion of the whole body, which would very quickly recover its former Figure. Though, if the agitation were too strong, some portions would be quite broken off, and presently turn'd into little Globes.

Exp. XI. I tried to produce another *Phænomenon*, that would not have been unpleasant, by putting together in a somewhat large Vessel, with other Liquors, two Oils, (whereof one, if I mistake not, was from *Turpentine*;) which first, by reason of the *Oleaginous* nature wherein they agreed, might exactly mingle and make a compounded Liquor; and then, by reason of their being one heavier, and the other lighter *in specie* than Water, might by this Liquor be again separated, and include betwixt them the Liquor that had divided them. But I found, that the *Oils* being once united would not be easily parted, but according to the Prevalency of the lighter or heavier Ingredient, in the mixture, the compounded Oil, would almost totally either emerge to the top of the Water, or lie beneath the bottom of it; I say, almost *totally*, because some parts of the Oil, which was not perhaps all uniformly mixt, did not keep in a body with the rest; but either was separated from the Mass in the form of Globuls, or else, sticking to the side of the Glass, had the other part of its *superficies*, which was contiguous to the Water, very variously figur'd, according as the bulk and degree of Gravity of the adhering Oil and other circumstances happen'd to determine. And 'tis chiefly upon the account of this various and odd Figuration of our mixture, that I here make mention of this Trial; which though it prov'd not successful to me, yet perhaps may succeed in the Hands of another, that shall make it with more leisure and diligence, than I could afford it.

These are some of the *Phænomena* I observ'd in Oil of *Turpentine*, when 'twas environ'd only with Fluids; but, if it were permitted to be contiguous to the inside of the Glass, and so to fasten part of its surface to a Solid, the greater part of the Surface, which remain'd exposed to one or both of the contiguous Liquors, would, partly by their action, and partly by the gravity of the Oil it self, be put into Figures so various, and sometimes so extravagant, that 'twas much more pleasant to behold them, than it would be easie to describe them; which therefore I shall not here attempt to do.

Whereas

Whereas I intimated in the Preamble to these Notes, Exp.XII. that *Confining Fluids* may have distinct Surfaces, without having, at least in many Positions, refractions differing enough, or reflections strong enough, to make the Plain, that distinguishes them, obvious to the Eye; I shall here observe, that when the Oil of *Tartar*, or *Nitrous Alkali*, that I employed, happened to be very clear and colourless, I have more than once made highly rectified *Spirit of Wine* float upon it so, that in most Positions the Vial seem'd to have in it but one Uniform Liquor; the Plain that divided the two Fluids being unapt to be discerned, but in a Position, wherein the Rays of Light passing thence to the Eye, fell very obliquely on it; and indeed, when there was no little Dust or other Feculency, swimming upon the *surface* of the Oil of *Tartar*; I had sometimes much ado to convince ordinary Spectators, that the Vial, in two distinct Regions of it, contain'd two unsociable Liquors.

On this occasion, I shall add an Experiment, which, Exp.XIII. though it does not so directly belong to our Subject, as to make its Omission a fault, is not yet perhaps so Impertinent as to be unwellcom.

We took a deliquated *Alkali*, made of *Niter* and *Tartar*, and deeply ting'd with *Cochaneel*; and, that the Liquors might not only be heterogeneous, but as differing in gravity and density as we could make them, we poured on it a peculiar kind of Oil lighter than *Spirit of Wine*, and holding the Plain where the two Liquors were contiguous in a convenient Position, in respect of the Light and the Eye, I observ'd it to make a strangely vivid Reflection of the incident beams of Light: so that this Physical Surface, which was flat, look't almost, for 'twas not so specular, like that of *Quicksilver*; and when I kept it till Night, and considered it by the Light of a Candle, the bright Figure of the flame was strongly reflected almost as from a close Specular body; which tempted me to suspect, that there might be something else than the bare smoothness of the surface of the *Alcalizat* Liquor to produce so brisk a Reflection; and the rather,

because I did not observe, that the Remains of the same tinged *Alkali*, which I kept in another Glass, nor a portion of the same Oil, which I had also by me in a separate Vial, did either of them afford so vivid a Reflection from its surface; though I did the less wonder at this, because of the great disposition to reflect Light, which I had formerly the Curiosity to observe in the forementioned Oil, when I joyned it with other Liquors. But, whether this strongly Reflecting power, taken notice of in our late recited Experiment, proceeded from some mixture, as it were, or confusion of singly unperceived particles in the Physical *Superficies* or Plain, where the two Liquors confine; or, whether some such *Materia subtilis*, or *Æthereal* Fluid, as *Cartesius* and some of the Ancients maintained, insinuated it self between our two Liquors, and made the Determinating surface more specular; or whether the *Phænomenon* be rather due to some other cause, I shall not now stay to make Inquiry: But to help towards it, I shall add on this occasion, that looking on this Liquor, as a body, which, though it have all the necessary Qualities of an Oil, does, in regard of its Origin, and some properties I have found in it, differ from common Chymical Oils; I was invited the more to observe its *Phænomena* in reference to Reflection, and I found, among other Things, (not pertinent to this place,) *First*, That the Confining Plain, often mentioned between the tinged *Alkali* and this Liquor, did not appear Red it self, nor communicate that Colour to the image of the Flame of a Candle reflected from it. *Secondly*, that when I warily shook the Vial, which contained the two Liquors, the uppermost would be reduced into a seeming Froth, consisting of a great number of imperfectly Globular bodies, which after a while would make a kind of a rude Physical Plain; which, though neither very Horizontal nor sensibly smooth, would, at its upper *superficies*, send back the incident Light with more briskness than one would expect; and when the seeming Froth consisted of smaller particles, these, when they were of a certain size, and conveniently placed, in reference to the Flame of a Candle and the Eye, would, (as more than one Trial informed me,) reflect the Incident Light so many waies, and so visibly, that they

they seemed, for multitude and splendor, like little sparkling Corpuscles of polished Silver; or almost like those glittering ones, that appear, when a clean plate of *Copper* is first immersed into a much allayed solution of good *Silver*, made in *Aqua fortis*.

And to these two *Phænomena* I shall add a *third*, which is, That, though pure *Spirit of Wine* be so thin a Liquor, and our *Oil* is nevertheless so light as to swim upon it; yet I found the Confining surface very strongly reflexive. But of this Liquor, more perhaps may be said in another place.

And it may, in the mean while, not be impertinent here to intimate to you, That I found, that some other *Essential Oils* (as Chymists call those, that are distilled with Water in *Limbeckes*) and particularly an unsophisticated *Oil of Lemons*, did, with our tinged *Alkali*, afford most of the same *Phænomena*; but not so brisk a Reflection: I say, *most*, chiefly because with *Spirit of Wine* these subtle Oils, as I formerly noted, will readily be confounded: though our *Anomalous Oyl* be unsociable with it.